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System Test Results of the Advanced Technology Anti-G Suit (ATAGS)

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Previous centrifuge and flight testing have shown that the ATAGS offers superior G endurance protection even when operated at lower pressures than the standard anti-G suit. All of the previous ATAGS testing was done, however, using human test subjects for the purpose of evaluating G protection. The purpose of the parametric tests was to provide basic system data such as volumes, fill rates, and pressure differentials for the ATAGS. In order to allow direct comparison with data taken previously on the AF standard anti-G suit (CSU-13A/P), these tests were based on procedures detailed in SAM-TR-78-12, Engineering Test and Evaluation During High G, Vol III: Anti-G Suits. ATAGS volumes were measured using pressure change during expansion from a known volume. The volumes of several suit sizes were taken, both with the suit unmounted and mounted on a mannequin to a proper fit. Total flow was measured with a flowmeter in the main fill hose. Differential pressure in various parts of the suit during rapid fill was measured at test points located on both sides of the abdominal bladder, on each thigh, and at the bottom of each leg. Preliminary data from these tests are presented.

Anti-G | Anti-G Suit | G Endurance | G suit | 8
G Tolerance | G-Induced Loss of Consciousness

Unclassified | Unclassified | Unclassified | UL

SYSTEM TEST RESULTS OF THE ADVANCED TECHNOLOGY ANTI-G SUIT (ATAGS)

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ABSTRACT

Previous centrifuge and flight testing have shown that the ATAGS offers superior G endurance protection even when operated at lower pressures than the standard anti-G suit. All of the previous ATAGS testing was done, however, using human test subjects for the purpose of evaluating G protection. The purpose of the parametric tests was to provide basic system data such as volumes, fill rates and pressure differentials for the ATAGS. In order to allow direct comparison with data taken previously on the AF standard anti-G suit (CSU-13A/P), these tests were based on procedures detailed in SAM-TR-78-12, Engineering Test and Evaluation During High G, VOL III: Anti-G Suits. ATAGS volumes were measured using pressure change during expansion from a known volume. The volumes of several suit sizes were taken, both with the suit unmounted and mounted on a mannequin to a proper fit. Total flow was measured with a flowmeter in the main fill hose. Differential pressure in various parts of the suit during rapid fill was measured at test points located on both sides of the abdominal bladder, on each thigh, and at the bottom of each leg. Preliminary data from these tests are presented.

BACKGROUND

In 1976 an extensive battery of tests were conducted on six operational and experimental Anti-G Suits (AGS) at the USAF School of Aerospace Medicine, Brooks AFB, TX. The results of these tests were published in SAM-TR-78-12, Engineering Test and Evaluation at High G, Volume III: Anti-G Suits (1). Although extensive manned testing of the ATAGS has been done, both on centrifuges and in flight test, complete basic parametric testing of the ATAGS has not been done to date.

The purpose of the tests reported in this paper is to perform a parametric engineering test and evaluation of the ATAGS to provide data for comparison to other AGS, or for future AGS or Anti-G Valve design considerations.

APPROACH

Tests were accomplished both with the ATAGS mounted on a mannequin (Stretch Volume) and unmounted lying flat on a table (Open Volume). All of the tests were conducted in a laboratory. Future verification tests are planned using human test subjects. All tests (except unmounted) were accomplished with the mannequin seated in a representative aircraft ejection seat with a 13 degree back angle. The mannequin was restrained in the seat in a manner representing the typical fighter aircraft restraint system. None of the ATAGS volumes reported include the volume of the pressure socks. Three iterations of each test were done to allow statistical analysis of data recorded.

METHOD

It is most important for these tests that the leakage from the ATAGS bladders and the test setup itself be minimized. Suits and plumbing were carefully checked before any tests were accomplished. The test set-up for these tests consists of a tank of known volume (measured with water and a graduate). This tank was raised to an initial pressure, measured with a transducer at the tank. A mild vacuum was applied to the anti-G suit (AGS) to assure repeatability for all tests and to evacuate the suit such that, ideally, the initial volume was zero. A valve in the line between the tank and the AGS under test was cracked and the AGS slowly raised to the desired pressure, measured by a transducer at the AGS inlet hose. Since the pressure change was made slowly and for small pressure differentials, this is considered an isothermal process, and the volume of the AGS can be determined because of the conservation of mass, using the relationship:

$$\mathrm{Sum}(P1*V1) = \mathrm{Sum}(P2*V2)$$

Volumes of all test setup plumbing and equipment were carefully measured and included in calculations.

Open volumes were measured with the AGS laid out flat, laces tightened to a "normal" dimension, and all zippers closed. Runs were accomplished by slowly increasing pressure from 0 to 5 psig where final volume calculations were made. Stretch volumes were measured with the AGS fitted to a mannequin. The mannequin was seated in an ejection seat, with a 13 degree back angle, and secured to the seat in a manner such that the actual aircraft restraint system was duplicated as far as possible. The mannequin's legs were positioned to approximate the height of aircraft rudder pedals. For these tests, pressure was increased from 0 to 10 psig in 1 psig steps. Pressure data were recorded and volumes were calculated at each step.

Three iterations of each test were accomplished for statistical analysis. All data were recorded manually or on a strip chart recorder.

RESULTS

In order to establish a baseline for comparison of ATAGS volumes and to validate the test apparatus and techniques, "open volume" measurements were made on the CSU13B/P and compared to the data for the CSU13A/P (1). Results of these tests are shown in Table 1.

Run Number	CSU13A/P	CSU13B/P
1	14.11	12.60
2	14.23	12.85
3	14.12	13.19
4	14.27	13.11
5	14.21	13.23
MEAN	14.19	13.00

Table 1.
Comparison of Open Volumes in Liters of the CSU13A/P and the CSU13B/P.

Table 2 presents the volumes of the CSU13B/P Med-Reg AGS fitted to the test mannequin. The Med-Reg AGS represented a "good fit" on the mannequin and is most representative of what might be expected on an average aircrew member.

AGS Pressure (psig)	Mean Vol (Liter)	Sigma
0.5	1.62	0.16
1.0	2.42	0.09
2.0	3.34	0.11
3.0	4.01	0.08
4.0	4.46	0.11
5.0	4.77	0.05
6.0	5.14	0.07
7.0	5.52	0.02
8.0	5.78	0.04
9.0	6.21	0.12
10.0	6.40	0.09

Table 2. Med-Reg CSU13B/ Stretch Volumes on Mannequin

Table 3 presents the volumes of the ATAGS fitted to the mannequin in a "good fit" condition. These data can be compared to the data presented in Table 2.

AGS Pressure	Mean Vol	Sigma
(psig)	(Liters)	
0.5	2.81	0.11
1.0	3.89	0.11
2.0	5.01	0.06
3.0	5.84	0.08
4.0	6.35	0.05
5.0	6.97	0.06
6.0	7.46	0.21
7.0	7.88	0.11
8.0	8.31	0.09
9.0	8.79	0.02
10.0	9.21	0.10

Table 3. ATAGS Stretch Volumes on Mannequin (Good Fit)

Table 4 presents the volumes of an ATAGS loosely fitted to the test mannequin. This condition might represent an aircrew member wearing an ATAGS that was one size too large or very poorly fitted.

AGS Pressure	Mean Vol	Sigma
(psig)	(liters)	
0.5	7.02	0.15
1.0	8.11	0.29
2.0	9.31	0.15
3.0	9.58	0.22
4.0	10.40	0.11
5.0	10.30	0.36
6.0	10.78	0.14
7.0	10.94	0.29
8.0	11.53	0.15
9.0	11.24	0.35
10.0	11.57	0.12

Table 4. ATAGS Stretch Volumes on Mannequin (Loose Fit)

Table 5 compares the volumes of the properly fitted and loosely fitted ATAGS on the test mannequin. These data are presented graphically on Fig. 1.

SUIT PRESSURE (psig)	GOOD FIT (liters)	LOOSE FIT (liters)
0	0	0
0.5	2.81	7.02
1	3.89	8.11
2	5.01	9.31
3	5.84	9.58
4	6.35	10.4
5	6.97	10.3
6	7.46	10.78
7	7.88	10.94
8	8.31	11.53
9	8.79	11.24
10	9.21	11.57

Table 5. ATAGS Loose Fit vs Good Fit on Mannequin

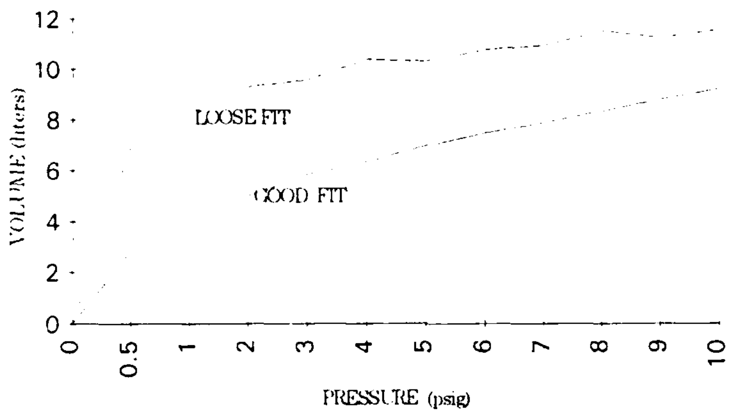

Fig. 1. ATAGS Loose Fit vs Good Fit on Mannequin

Table 6 compares the volumes of a properly fitted CSU13B/P and a properly fitted ATAGS on the test mannequin. These data are presented graphically on Fig. 2.

SUIT PRESSURE (psig)	ATAGS AVG VOL (liters)	CSU13B/P AVG VOL (liters)
0	0	0
0.5	2.81	1.62
1	3.89	2.42
2	5.01	3.34
3	5.84	4.01
4	6.35	4.46
5	6.97	4.77
6	7.46	5.14
7	7.88	5.52
8	8.31	5.78
9	8.79	6.21
10	9.21	6.4

Table 6. ATAGS vs CSU13B/P Volumes on Mannequin

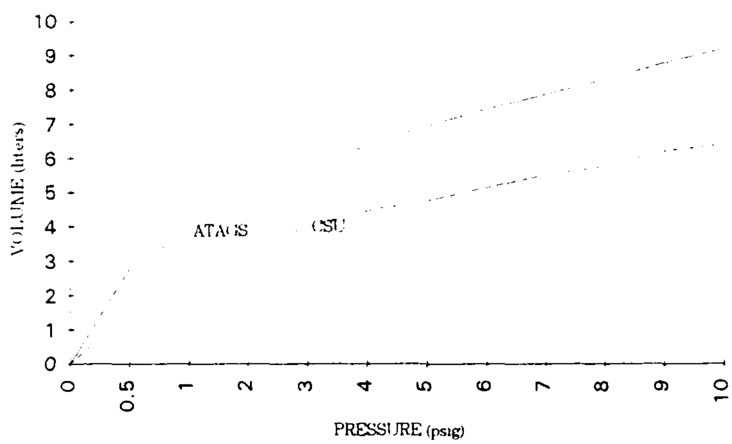

Fig. 2. ATAGS vs CSU13B/P Volumes on Mannequin

Table 7 compares the projected volumes for the ATAGS and CSU13B/P fitted to a human. These data are estimated from a scaling factor derived from actual data (1).

SUIT PRESSURE (psig)	CSU 13B/P (liters)	ATAGS (liters)
0	0	0
0.5	2.14	3.71
1	3.19	5.13
2	4.41	6.61
3	5.29	7.71
4	5.89	8.38
5	6.30	9.20
6	6.78	9.85
7	7.29	10.40
8	7.63	10.97
9	8.20	11.60
10	8.45	12.16

Table 7. Comparison of ATAGS vs CSU13B/P Calculated Volumes on a Human Subject

DISCUSSION

Table 1 compares the volumes obtained for the CSU13B/P, using our current test set-up and instrumentation, with the volumes obtained for the CSU13A/P (1). The results obtained with our current technique indicate a reasonable correlation between the volumes of the two AGS, given the difference in outer covering material, cotton for the CSU13A/P and a blend of Nomex/Kevlar for the CSU13B/P. It is believed that the cotton material could allow the CSU 13A/P to stretch a little more (1) and account for the slightly greater volume. The CSU13B/P AGS volumes were used as baseline data for the remaining tests.

Table 2 displays the stretch volumes for a Med-Reg CSU13B/P AGS properly fitted to the test mannequin. These data do not correlate well with similar testing of the CSU13A/P (1), although the techniques used were very similar. In some cases current testing of the CSU13B/P yielded volumes that were less by a factor of 2 than the volumes of the CSU13A/P (1). As is shown in Table 1, the open volume of the "A" model is larger, but not enough to account for the differences found in the stretch volume measurements. After a good deal of "trial and error" testing it was discovered that AGS volumes determined in the tests being conducted were very sensitive, not only to AGS fit, but also to the position of the mannequin in the seat and the method of restraint used. In the earlier work (1) the mannequin had been seated in a standard office chair and was not restrained beyond securing the legs to the chair to prevent leg extension during AGS pressurization. As is detailed above, our current testing was being done with the mannequin in an ejection seat and restrained in a manner representing an aircraft configuration. When the mannequin was configured in a position similar to that used in the earlier work (1), volume data correlated quite well. This experience may serve as a caution to others involved in this type of testing that extreme care must be taken to duplicate mannequin position and restraint conditions if the data is to be directly compared with other test data. Such considerations also bring into doubt any volume data extrapolated to other conditions. This concern will be further discussed later in this section.

Table 4 displays the volumes taken for an ATAGS very loosely fitted to the mannequin. This probably represents an extreme in that very few pilots would fly with their G-Suit fitting worse than this.

Table 5 and Fig. 1 compare the volumes of a properly fitted and a loosely fitted ATAGS on the test mannequin. An interesting and important point to note on Fig. 1 is that after the initial "dead volume" is taken up, the slope of the pressure line for both ATAGS fit conditions is very similar. This would indicate that even a poorly fitted ATAGS could provide superior G protection.

Table 6 and Fig. 2 compare the volumes of the ATAGS with the CSU13B/P, both properly fitted to the mannequin. The ATAGS requires a little over one liter to fill to the 0.5 psig point and exhibits a slightly higher slope throughout the pressurization schedule, requiring 2.8 liters more at the 10 psig point than the CSU13B/P. It should also be pointed out that the ATAGS volumes do not include the volume of the pressure socks. These socks are still in development and will be tested separately.

Table 7 displays estimated volumes for the ATAGS properly fitted on a human subject. In previously published data (1), stretch volumes are included for the CSU13A/P on a human subject as well as a mannequin for pressures up to 10 psig. The factor of difference between these two conditions was found to be 1.32. The data in Table 7 was calculated by applying this factor to the data in Table 6. Because of the sensitivity of the volume being measured to position and restraint configuration, the data in Table 7 are highly suspect and requires verification using a human test subject.

Conclusion

The methods and instrumentation used for measuring AGS volumes in this study are valid and accurate. Volume measurements are very sensitive to mannequin position and restraint configuration. The Med-Reg ATAGS requires about 2.8 more liters of air at 10 psig when mounted on a mannequin than does the CSU13B/P. This does not include the volume of the pressure socks. Methods used in this study, to date, have been validated and the study is in progress.

REFERENCES

1. Thompson, Roy W., L. Meeker, G. Wilson, A. Krueger, P. Love, Engineering Test and Evaluation During High G Vol III, SAM-TR-78-12. June 1978.